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EFFECT OF CHILLS ON SAND CASTING OF ALUMINIUM ALLOY

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ABSTRACT

This study investigated the effect of chill in the sand casting of aluminum alloy. Eight cylindrical rods of dimension 7.5mm × 40mm and a four-disc shape sample were cast using a sand mould. Alumina Oxide, Iron filling, and Zinc chills were stirred into the melt of three sand molds and the last sample was left unchilled. The investigation involved testing of mechanical properties and metallographic analysis of cast samples. The results revealed that the sample chilled with zinc has the highest mechanical properties but the lowest wear resistance (Tensile strength of 155.23312MPa, hardness of 50.24559BHN). Also, the sample chilled with alumina oxide revealed an evenly distributed microstructure due to its unique properties and its highest wear resistance. The iron filling chill sample displayed very close mechanical properties with the sample without chill (Tensile strength of 133.56225MPa, hardness of 43.18315BHN) (Tensile strength 133.85680Mpa, hardness of 42.94031BHN).

KEYWORDS: casting, sand mould, mechanical properties, hardness, tensile strength

1. INTRODUCTION

This study investigates the process of casting, majorly the sand-casting process. The standard sand-casting process and it enhanced process. Casting is a traditional and widely practiced manufacturing process that has been in use for thousands of years. It is a versatile method for producing complex metal component by creating moulds from a mixture of sand and binders (Ibhadode, 2001). Casting is a process in which material such as metal or plastic in molten form is poured into a mold and allowed to solidify, in order to make parts or products. Casting is the most standard way of making complex metal shapes. Intricately shaped components that are difficult to produce by other methods can be produced by casting. Heavy equipment like machine tool beds, ships propellers, etc. can be cast easily in the required size, rather than fabricating by joining several small pieces. Casting can be used to produce metal parts in bulk quantities, as a result, making it suitable and reliable for mass production. Furthermore, to meet specific requirements,

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there are different types of casting that differ by the material and mold used. Casting can be broadly divided into two main categories as expendable and nonexpendable mould casting. It can also be classified according to the mould material used to cast the metal such as sand casting, ceramic casting or metal mould casting and depending on the pouring methods as gravity casting, low pressure dies casting and high pressure die casting (Navaneeth, 2009). Sand casting is one of the oldest and most fundamental methods of metal casting used in the manufacturing industry. Sand casting dates back thousands of years and is believed to have been used first by ancient civilizations such as the Egyptians and Chinese. It was one of the major key techniques for creating metal objects and tools. Pure aluminum is a soft, durable, lightweight, malleable, silverish white metal. Aluminum base alloys are used in automobile industry, air craft industry and other general engineering industries due to their good corrosive resistivity and good strength to weight ratio (Saradaet al., 2013). In most cases, superior mechanical properties are needed for numerous applications, so the performance of the alloy has been the subject of many mechanical investigations. Since strength and hardness of the alloys are mainly depended on their microstructure, a lot of efforts have been done for refining microstructure of castings in order to improve the mechanical properties of the alloys. Addition of modifier and refiner to the melt is the common method, which in general, is adopted by many researchers (Saradaet al., 2013).

2.0 MATERIAL AND METHODOLOGY

2.1 MATERIALS

• Aluminum alloy: Aluminum alloy was bought from a market in Akure.

• Chills: Zinc (Zn), Alumina Oxide (Al_2O_3) and Iron filling (Fe) were used in the research work.

• Foundry sand: Foundry sand and other addictive used in this study were made available in Metallurgical and Material Department foundry workshop of one of the Federal University in South West Nigeria.

2.2 EQUIPMENT

- Furnace: The melting of the matrix and reinforcement was carried out on a gas fired furnace available in the metallurgical and material school of science foundry workshop.
- Brinell hardness tester: Brinell hardness test machine was used to carry out the hardness test of the sample.
- MonsatoTensiometer: Monsatotensiometer was used to carry out the tensile test.
- Taber type abrasion tester: Wear resistance test was carried out with Taber type abrasion wear testing machine.
- Optical metallurgical microscope: Microstructural examination was conducted with the optical metallurgical microscope.

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2.3 EXPERIMENTAL PROCEDURE

The experimental procedures of this study consist of:

Mould preparation

Moulding sand was produced with a green sand. The constituent of a green sand is synthetic silica sand, bentonite and moisture. The synthetic silica sand was first sieved, some proportion of bentonite and moisture was added to it. After it attains the required moisture level it is poured into the cope and drag to form the shape of the pattern placed inside.

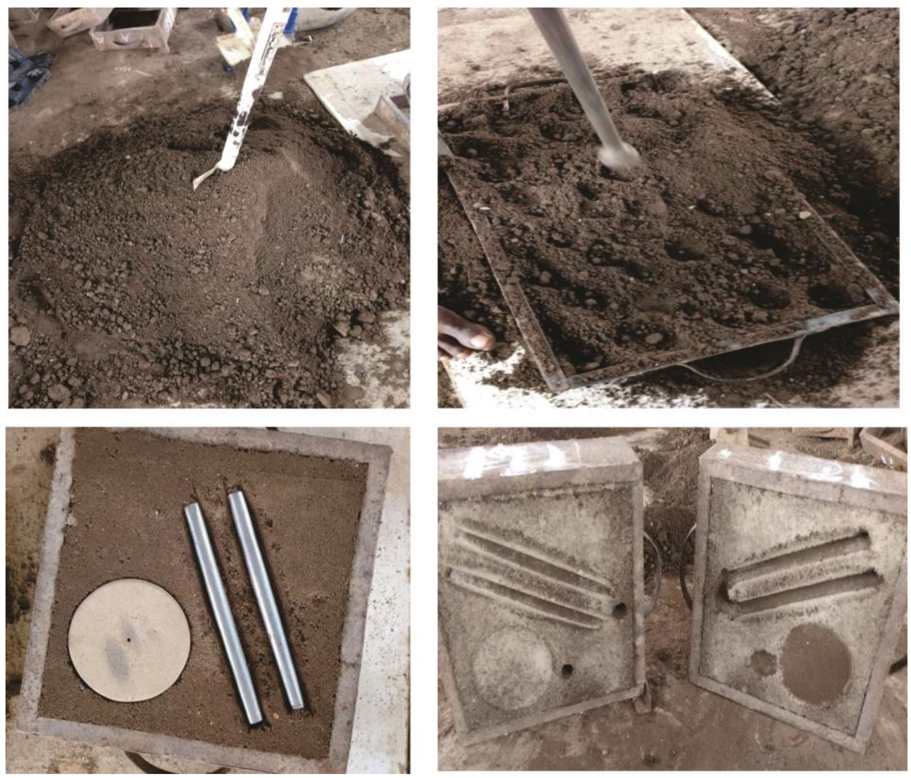

Fig.1: Sand mould preparation process

2.3.1 Casting of the alloy

The casting of the alloy was carried out with a stir-casting technique. Eight sample of aluminum magnesium silicon alloy (AlMgSi) were cast by melting the matrix part on a gas fired furnace. After melting the matrix, the chill material is added to the melt stirred carefully, then continue melting till it ready to be poured into the mould cavity. Where, four sample for the impact strength test and the other four for the hardness and metallographic examination test. The sample geometry is of cylindrical shape of diameter 7.5mm with length of 40mm. The castings were labeled as sample 1, 2, 3 and 4 accordingly.

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Also, four different samples were cast to a disc shape as seen in the mould for the wear test. All samples were properly reinforced with chill and one was left unchilled in each sample to serve as the control.

Table 1: The melting point of the matrix and chill materials.

	AlMgSi	Fe	Al_2O_3	Zn
Melting point	595°C	1535°C	2072°C	419.5°C

Table 1.1: Elemental Composition of the samples. Each sample weigh 500g.

Samples	AlMgSi	Fe	Al_2O_3	Zn
1	100%	Nil	Nil	Nil
2	70%	30%	Nil	Nil
3	70%	Nil	30%	Nil
4	70%	Nil	Nil	30%

Fig.2: Sample casting process.

2.3.2 Tensile strength test

The tensile test specimens were machined from the cast samples. The test piece was locked securely within the grips of the Tensometer machine. The test piece was stretch with force generated from manually operating the screw attached to the Tensometer until the test piece broke apart. The load and extension

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data available from the graph sheet attached to the machine were converted to specific values of stress and strain. The geometry of the tensile test sample is shown below.

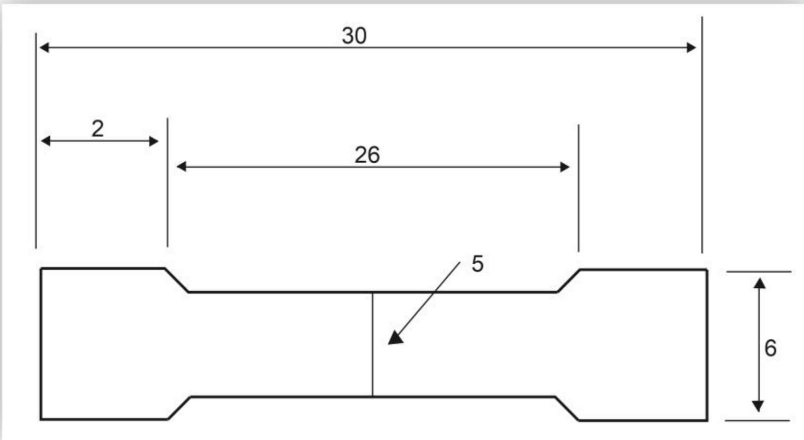

Fig.3: Dimension of the tensile sample

2.3.3 Brinell hardness test

An indentation hardness test that uses a verified machine to force an indenter (tungsten carbide ball with diameter), under specified condition into the surface of the material under test. The diameter of the resulting indentation is measured after the removal of the force. The indentor is brought into contact with the test specimen in a direction perpendicular to the surface, and the test force is applied within 1 to 8 seconds. The test force is held for a specified dwell time and then removed (maintain fully applied test force for 10s to 15s). The diameter of the indentation is measured in two directions perpendicular to each other. The brinell hardness value is determined from the mean of the diameter measurements. This procedure was repeated for the remaining samples.

2.3.4 Wear test

The test is performed using a Taber Rotary Platform Abraser. Mounting a flat disc specimen to a turntable platform that rotates on a vertical axis at a fixed speed. Two Taber abrasive wheels, which are applied at a specific pressure, are then lowered onto the specimen surface. As the turntable rotates, characteristic rub-wear action is produced by contact of the test specimen against the sliding rotation of the two abrading wheels while a vacuum system removes loose debris. The wheels traverse a complete circle on the specimen surface, and the resulting abrasion marks form a pattern of crossed arcs in a circular band that cover an area approximately 30 cm2(Taber Industry, 2017).

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2.3.5 Metallographic examination

Four specimens were prepared from the four aluminium alloy samples for metallographic examination. The procedure consists of cutting, successive grinding using silicon carbide grit paper of 240, 320, 400 and 600 microns. Polishing was carried out on a rotating cloth to ensure mirror-like surface. A solution containing 5ml nitric acid, 2ml hydrofluoric acid and 100ml of distilled water was used to etch the specimens for about 10 seconds. The specimens were observed under Digital Metallurgical Microscope where the micrographs of the specimens were recorded at a magnification of 50X.

3. RESULTS AND DISCUSSIONS

3.1 RESULTS

The results of the test carried out are shown in the table below:

Table 2: Aluminum alloy chemical analysis.

Grade	SI	FE	MN	MG	CU	TI	ZN	CR	PB	AL	OTHER
SAMPLE	0.48	0.18	0.04	0.52	0.05	0.02	0.05	0.01	0.01	98.5	0.02

3.1.1 Hardness result

Table 3: Hardness result

SAMPLES	First direction (BHN)	Second direction (BHN)	Average (BHN)
1	44.15752	41.72309	42.94031
2	42.05294	44.31336	43.18315
3	45.02637	46.41005	45.71821
4	51.52816	48.69301	50.24559

3.1.2 Tensile strength

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Table 4: Tensile results

	Length (mm)	Thickness (mm)	Width (mm)	Diameter (mm)	Maximum Tensile stress (MPa)
1	30.00000			5.00000	133.85680
2	30.00000			5.00000	133.56225
3	30.00000			5.00000	130.57649
4	30.00000			5.00000	155.23312
Mean	30.00000			5.00000	138.30716
Standard Deviation	0.00000			0.00000	11.38085

	Load at Maximum Tensile stress (N)	Tensile strain at Maximum Tensile stress (mm/mm)	Tensile extension at Maximum Tensile stress (mm)	Energy at Maximum Tensile stress (J)	Tensile stress at Break (Standard) (MPa)
1	2628.27203	0.03222	0.96675	1.10910	133.85680
2	2622.48851	0.03000	0.89994	0.80826	133.56225
3	2563.86325	0.03389	1.01675	1.05069	130.57649
4	3047.99508	0.03333	0.99987	1.12335	155.23312
Mean	2715.65472	0.03236	0.97083	1.02285	138.30716
Standard Deviation	223.46248	0.00172	0.05162	0.14647	11.38085

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Mean	2715.65472	0.03236	0.97083	1.02285
Standard Deviation	223.46248	0.00172	0.05162	0.14647

3.2 Metallographic examination

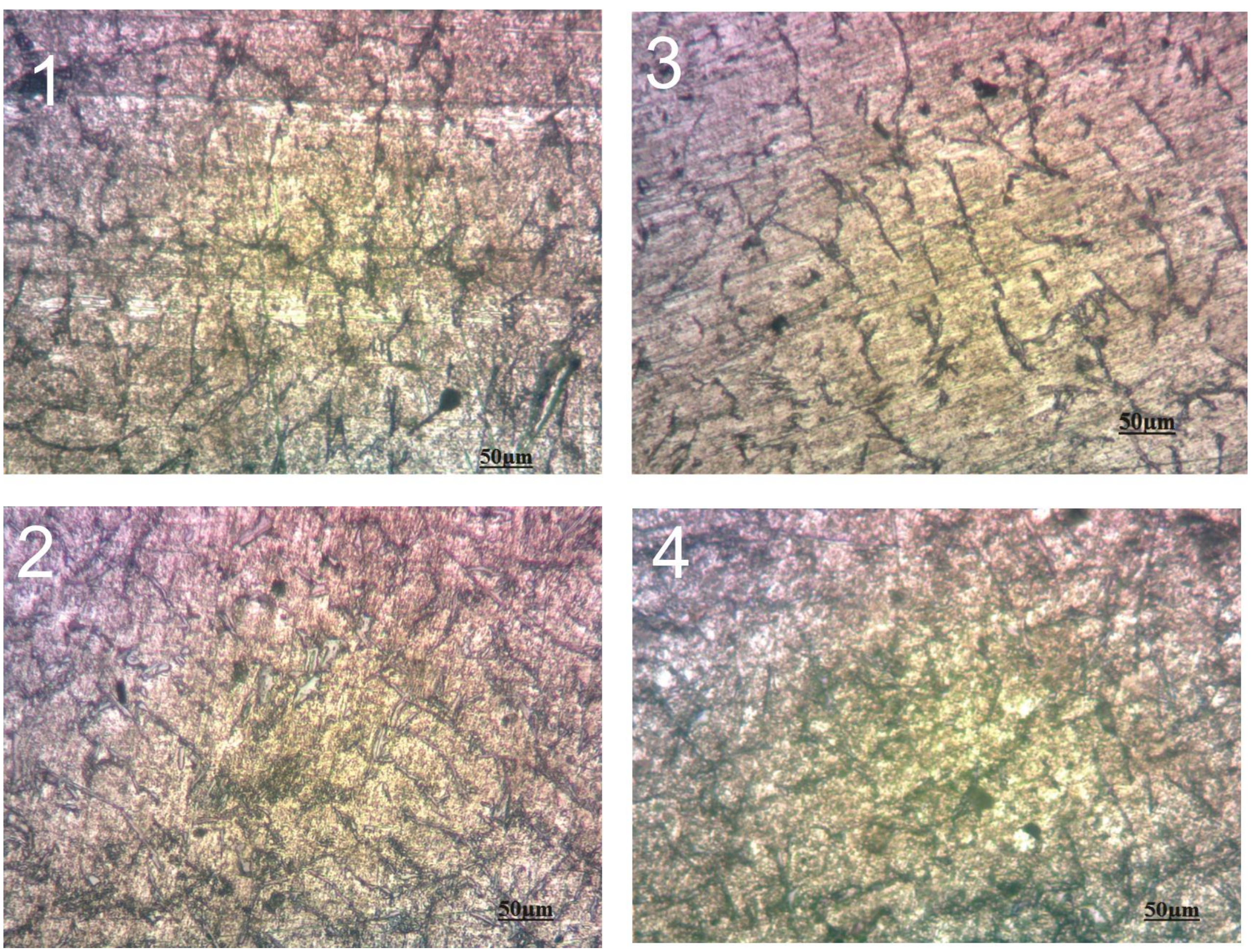

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Fig.5 – Metallographic examinations

3.2.1 Wear test

Table 5: For 500g at 1000rpm

SAMPLES	INITIAL WT	FINAL WT	DIFF IN WT	DIFF. WT/RPM× 1000	WEAR RATE
1	132.79	132.72	0.07	0.07/500g	0.14
2	136.53	136.48	0.05	0.05/500g	0.1
3	138.87	138.76	0.11	0.11/500g	0.22
4	149.48	149.31	0.17	0.17/500g	0.34

Table 5.1: For 750g at 1000rpm

SAMPLES	INITIAL WT	FINAL WT	DIFF IN WT	DIFF. WT/RPM× 1000	WEAR RATE
1	132.72	132.65	0.07	0.07/750g	0.093
2	136.48	136.36	0.12	0.12/750g	0.16
3	138.76	138.72	0.04	0.04/750g	0.053
4	149.31	149.27	0.04	0.04/750g	0.053

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Table 5.2: For 1000g at 1000rpm

SAMPLES	INITIAL WT	FINAL WT	DIFF IN WT	DIFF. WT/RPM× 1000	WEAR RATE
1	132.65	132.56	0.09	0.09/1000g	0.9
2	136.36	136.25	0.11	0.11/1000g	0.11
3	138.72	138.69	0.03	0.03/1000g	0.03
4	149.27	149.24	0.03	0.03/1000g	0.03

3.3 DISCUSSIONS

3.3.1 Hardness result

Table: 6.1: Influence of chill material on the hardness of aluminum alloy

SAMPLES	BRINELL HARDNESS NUMBER
1	42.94031
2	43.18315
3	45.71821
4	50.24559

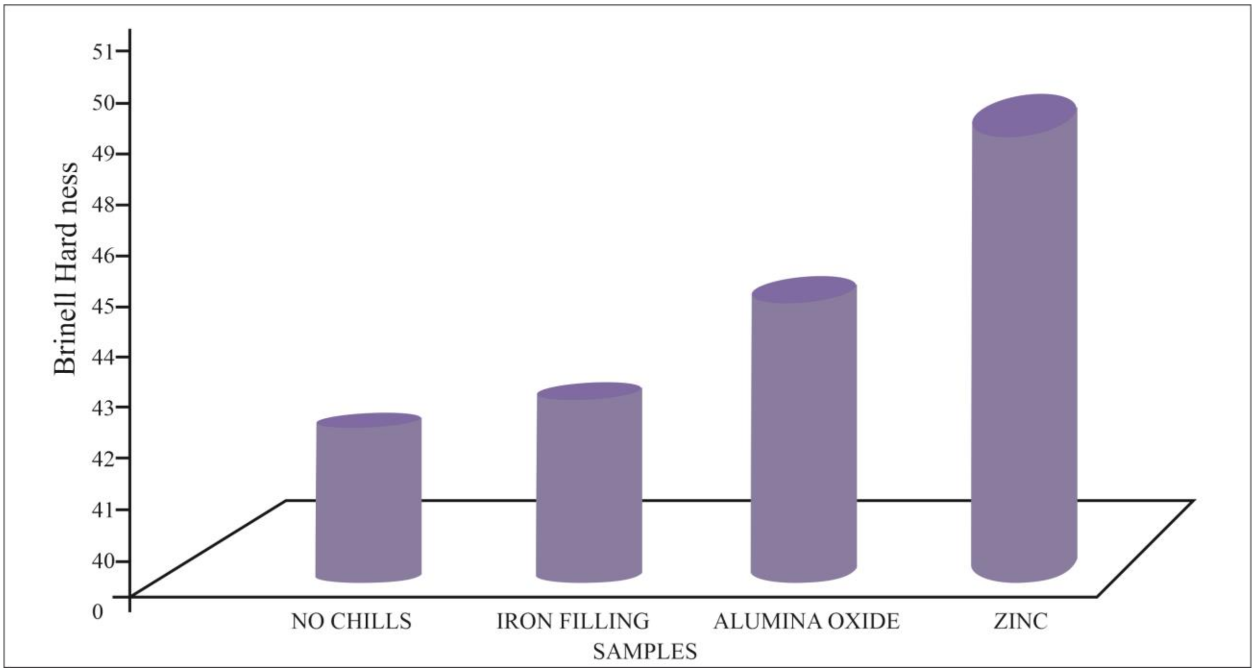

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Fig. 6: Chart of Tensile strength of samples with different chill materials

The chart of hardness value with different chill materials (Fig.6) shows that Zinc chill displayed the highest hardness value followed by Alumina Oxide chill then Iron filling chill. The casting with no chill shows the lowest hardness value. This is attributed to the fact that casting with Zinc chill gives rise to fine grains structure.

3.3.2 Wear Rate

Table 6.2: Influence of chill material on the wear rate of aluminum alloy

SAMPLES	WEAR RATE @ 500g	WEAR RATE @ 750g	WEAR RATE @ 1000g
1	0.14	0.093	0.9
2	0.1	0.16	0.11
3	0.22	0.053	0.03
4	0.34	0.053	0.03

Fig.7: Chart of wear resistance of samples with different chill materials

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The chart of wear resistance with different chill materials (Fig.7) reveals that at 500g applied mass the sample with Iron filling chill has the highest wear resistance closely followed by sample with Alumina Oxide then sample with Zinc chill. Cast sample with no chill has the lowest wear resistance. At 750g applied mass sample with Alumina Oxide and Zinc chill has the highest wear resistance then followed by cast with no chill. Cast sample with Iron filling has the lowest wear resistance. At 1000g applied mass sample Alumina Oxide and Zinc chill has the highest wear resistance then followed by sample with Iron filling chill. The cast sample no chill with has the lowest wear resistance, due to its unique properties.

3.3.3 Tensile strength

Table 6.3: Influence of chill material on tensile strength of aluminum alloy

SAMPLES	Maximum Tensile stress (MPa)
1	133.85680
2	133.56225
3	130.57649
4	155.23312

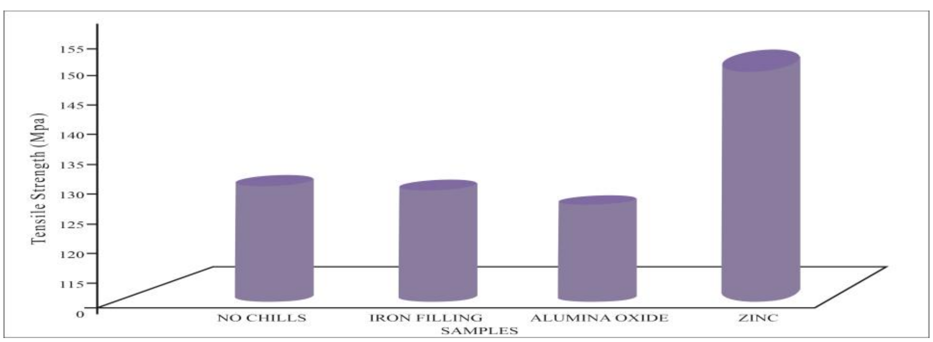

Fig. 8: Chart of Tensile strength of samples with different chill materials

A fine-grained material is harder and stronger than one that is of coarse grain structure as observed by William (2009). The chart of Tensile strength test with different chill materials (Fig.8) revealed that the casting with Zinc material displayed the highest tensile strength followed by the casting with no chill and Iron filling chill displaying a very close tensile strength. Cast sample with Alumina Oxide chill displayed the lowest tensile strength test. When compared to the cast sample with no chill, it indicates that Alumina Oxide reduced the tensile strength of the matrix material. The zinc chilled sample are characterized with finer grains structure with uniformly distribution of intermetallic particles due to high cooling rate and when the sample was subjected to tensile experiment, the material shows a high tensile strength before fracture occurred.

3.3.4 Metallographic examination

Figure 1-4: Optical micrographs of samples of cast aluminum magnesium silicon alloy using different chill materials. Samples: 1 - No chill, 2 - Iron filling chill, 3 - Alumina Oxide chill and 4 - Zinc chill. The black spots are interdendritic of chill material particles distributed in aluminum matrix (brownish back-ground). Brownish back-ground spot represents the alpha phase of the matrix grain while the black spot represent beta phase of eutectic chill grain (Leela and Sreenivas, 2012). Figure 1-4 show the microstructures of the cast components using zinc, Alumina Oxide, Iron filling chill and cast without chill. The microstructures indicate that the chill materials have decided effects on the grain size and also on the distribution of phases in the alloy. When the hot metal comes in contact with the chill materials, the melt experiences severe supper cooling. This results from a high rate of heat transfer of the melt in chilled samples. Hence the critical nucleus size of the solidified melt is reduced and a greater number of nuclei are generated, causing a finer microstructure (Kabiru, 2016). A close observation of Figure (1) shows magnesium and silicon grains appear larger when compared to other sample obtained from chilled casting of different materials. In figure 2, a microstructure of sample cast with iron filling chill, beta particles seem to have dissolved little as it grain structure looks finer than that of the unchilled sample. Figure (3) and (4) were chilled obtained from samples chilled with Alumina Oxide and Zinc. Alumina Oxide chill appear to have produced sample with the finest grain structure. Sample chilled with Zinc is just slightly different from the control sample (unchilled sample).

CONCLUSION

In this study, effect of chill material on the sand casting of aluminum alloy was investigated strictly base on it mechanical and microstructure properties. It was observed from the results that Zinc chill displayed the highest mechanical properties strength followed by iron filling chill with the least being alumina oxide. The mechanical properties vary with the chill unique properties. The following conclusions were drawn from the results and discussion:

- The use of chill materials influences the mechanical and microstructure properties of the aluminum alloy casting.

- The tensile strength of the aluminum alloy casting is improved by the use of different chill materials. Cast sample mix with Zinc chill displayed the highest tensile strength (155.23312Mpa) followed by sample with iron filling chill and no chill having a very close tensile strength (133.56225Mpa, 133.85680Mpa). With Alumina Oxide chill displaying the least strength.

- The hardness of the aluminum alloy is influenced by the use of chill. Sample with zinc chill displayed the highest improvement in the hardness level (50.24559BHN) followed by Alumina Oxide chill sample (45.71822BHN). With iron filling chill sample, a little bit higher than the control sample (43.18315BHN, 42.94031BHN).
- The wear rate of the aluminum alloy is influenced by the use of chill. The cast sample with Alumina Oxide chill best influence the wear resistance of the aluminum alloy by closely reducing it compared to the control sample. Cast sample with no chill has the lowest wear resistance followed by iron filling chilled sample.
- The use of chill material influences the Microstructure of the aluminum alloy casting.

REFERENCE

Ibhadode, A. O. A. (1991). Design and manufacture of a gas-fired furnace. Proceedings of the Third Uniben Conference on Engineering and Technological Development, Benin, pp 159-164.

Navaneeth, V. (2009). Developing an effective die cooling technique for casting solidification. Unpublished M.sc Thesis, School of Engineering, Auckland University of Technology.

Degarmo, E. Paul; Black, J T.; Kohser, Ronald A. (2003). Materials and Processes in Manufacturing (9th ed.). Wiley. ISBN 0-471-65653-4.

Sarada, B. N., Srinivasamurthy, P. L. and Swetha (2013). Micro structural characteristics of Sr and Na modified Al-Mg-Si alloy. International Journal of Innovation Research in Science, Engineering and Technology, 2(8), pp 3975-3983.

Mehdi, Dr. (2015). Effect of Silicon content on the Mechanical Properties of Aluminum Alloy. International Research Journal of Engineering and Technology. 2. 1326-1330.

Chastain Steve, (2004). snag Casting. A sand casting for small foundry. ISBN 978-0-9702203-2-5.
Helmenstine, Anne Marie, Ph.D. "Aluminum or Aluminium Alloys." ThoughtCo, Aug. 27, 2020, thoughtco.com/aluminum-or-aluminium-alloys-603707.

Chi-Yuan, C., Jun-Yen, U. and Te-Chang, T. (2006). Effect of cooling rate on Mg17Al12 volume fraction and compositional inhomogeneity in a sand-cast AZ91D magnesium plate. Materials Transaction, Japan Institute of Metals, 47(8), pp 2060-2067.

ISSN: 2582-6271

Vol. 5, Issue.3, May-June 2024, page no. 30-44

Mehr, F. F. Quantitative assessment of the effect of copper chills on casting/chill interface behavior and the microstructure of sand cast A319 alloy. Unpublished M.Sc Thesis, Department of Materials Engineering, University of British Colombia, Vancouver. 2012.

Rojas Gregorio, Jose. (2020). Re: On what basis reinforcement percentage is selected to prepare metal matrix composites? Retrieved from: https://www.researchgate.net/post/On-what-basis-reinforcement-percentage-is-selected-to-prepare-metal-matrix composites/5e68a9d229259b0224447c18/citation/download.

Samal, Priyaranjan. (2019). Re: On what basis reinforcement percentage is selected to prepare metal matrix composites? Retrieved from: https://www.researchgate.net/post/On-what-basis-reinforcement-percentage-is selected-to-prepare-metal-matrix composites/5d0862972ba3a1b17b60050d/citation/download.

Kumar, V. &Venkatesh, C. (2018). Effect of ceramic reinforcement on mechanical properties of aluminum matrix composites produced by stir casting process. Materials Today: Proceedings. 5. 2466-2473. 10.1016/j.matpr.2017.11.027.

(Das, D.K., Mishra, P.C., Singh, S. et al. Properties of ceramic-reinforced aluminum matrix composites - a review. Int J Mech Mater Eng 9, 12 (2014).)

Joel, H. (2001). Effect of chills on soundness and ultimate tensile strength (UTS) of aluminum alloy–corundum particulate composite. Journal of Materials and Design, 22, Published by Elsevier Science, pp 375-385.

Leela, B. N. and Sreenivas, K. V. (2012). Microstructure and micro hardness of chill cast AlB4C composites. International Journal of Mechanical Engineering and Robotics Research, 1(3), pp 450-456.

Olakunle F. Isamotu, Kabiru M. Raji 2019. Performance evaluation of different materials as chills in sand casting of aluminum alloy. ACTA TechnicaCorviniensis, Bulletin of Engineering. University POLITEIHNICA Timisoara, Faculty of Engineering Hunedoara. ISSN 2067-3809.

Kabiru M. Raji, A. Bello, K. Raji. Performance Evaluation of Different Materials as Chills in Sand Casting of Aluminum Alloy. Published 2016. Materials Science.